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Dual-standard colour television: an experimental investigation of two proposals relating to the NTSC system

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DUAL-STANDARD COLOUR TELEVISION : AN EXPERIMENTAL INVESTIGATION OF TWO PROPOSALS RELATING TO THE NTSC SYSTEM

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(1965/46)

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Section	Title	Page
	SUMMARY	1
1.	INTRODUCTION	1
2.	EXPERIMENTAL ARRANGEMENT	3
3.	SUBJECTIVE TESTS	6
4.	RESULTS OF SUBJECTIVE TESTS	9
5.	DISCUSSION OF RESULTS	10
	5.1. Visibility of Beat Pattern	10
	5.2. Impairment of the Luminance Component of the Translated Picture	10
	5.3. Total Impairment Introduced by the Translation Process	11
6.	CONCLUSIONS	11
7.	REFERENCES	11

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SUMMARY

If European broadcasters were at liberty to radiate on either the 625 lines, 50 fields per second or the 525 lines, 60 fields per second standards, the need for standards conversion between the American and European standards would be obviated. In this report, two proposals are described whereby the European standards could be chosen so as to enable such a dual-standard system with NTSC colour to be operated. These proposals have been made by the BBC and the Netherlands and are both concerned with the translation of signals between the American 525/60 standard and a European 525/60 standard. Tests have been carried out which show that both proposals would give acceptable translation. However, the BBC proposal results in a significant reduction in the visibility of the beat patterns occurring in the translation process as compared with the Netherlands' proposal.

1. INTRODUCTION

It has been proposed[1,2] that Europe should adopt dual television standards, the broadcasters being at liberty to transmit signals on 625 lines, 50 fields per second or 525 lines, 60 fields per second.* The 525/60 standard would be used when originating a programme intended for export to America - for example, by magnetic tape or by earth satellite - and when radiating a programme received from America. Other programmes would normally be originated on the 625/50 standard. The use of dual standards would obviate the need for standards conversion between the European and American standards. Conversion between colour television signals on different standards is likely to prove a difficult problem; from the point of view of colour television, therefore, the dual standards proposal is particularly advantageous.

If dual-standard colour television were adopted in Europe, it would be necessary for the 525/60 system to adopt the chrominance subcarrier frequency of approximately 4·43 Mc/s proposed for the European 625/50 system and not the frequency of 3·58 Mc/s used in America. Thus dual-standard colour television would require the removal of the chrominance subcarrier and its re-insertion at a new frequency whenever programmes were exchanged between America and Europe.

In order to avoid unacceptable complication in colour receiver design it would be imperative to use the same chrominance-subcarrier frequency in Europe for both the 525/60 and 625/50 standards. The precise value of the chrominance-subcarrier frequency must, however, be chosen to facilitate dual standards operation. In this connection, two proposals relevant to the NTSC system have been investigated experimentally:

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* For convenience, the two standards are referred to as '625/50' and '525/60' in this report.

(i) A BBC proposal[2,3] which utilises a chrominance-subcarrier frequency S = 4429764·7 c/s. This frequency is so chosen that it has an exact half line-frequency relationship on the European 625/50 standard ($S = 567\ L_1/2$ where L_1 is the European line-frequency) and is offset from an exact half line-frequency relationship by 17 times the picture frequency on the European 525/60 standard ($S = 563\ L_2/2 + 17\ F_2/2$ where L_2 and F_2 are the American line and field frequencies). The proposal preserves a low visibility of the sub-carrier-pattern on both European standards. In addition, the proposal results in a reduction of the visibility of the pattern caused by a beat between the new subcarrier frequency and any remnant of the original subcarrier frequency when transposing the chrominance information between the American and European standards. This occurs because the chrominance subcarrier frequency on the American standard is $S' = 455\ L_2/2$ so that the frequency of the beat frequency component would be $S - S' = 54L_2 + 17\ F_2/2$ which is a precision-best[3] relationship.

(ii) A Netherlands' proposal[4] which utilises a line-scan frequency for the European 525/60 and 625/50 standards which is identical with that of the American 525/60 standard. The chrominance subcarrier chosen is S = 4429195·2 c/s which has a half line-frequency relationship on both the 625/50 and 525/60 standard ($S = 563\ L_2/2$). However, in order that the field frequency of the European 625/50 standard should be close to 50 c/s, the number of scanning lines is increased from 625 to 629 so that the standard is actually 629/50. It should be noted that the difference-frequency component giving rise to the beat pattern between the new and original subcarriers will be an integral multiple of the line-scan frequency ($54L_2$) and will thus be of maximum visibility.[3]

An earlier report[5] describes tests made to determine the relative visibility of c.w. interference at a frequency equal to that of a beat between the American and European subcarriers when:

(a) The difference-frequency differs from a multiple of the line-scan frequency by an odd multiple of half the field-scan frequency as in the BBC proposal ((i) above).

(b) The difference-frequency is equal to an integral multiple of the line-scan frequency as in the Netherlands' proposal ((ii) above).

The results of these tests indicated that the BBC proposal would have a definite advantage over the Netherlands' proposal since condition (a) gave a reduction in visibility of the pattern equivalent to that resulting from a reduction of at least ten decibels in the difference-frequency component.

Further subjective tests have been made[6] to assess the visibility of the subcarrier pattern on the compatible picture when:

(c) The subcarrier frequency is an exact odd-multiple of half the line-scan frequency as in the normal NTSC system.

(d) The subcarrier frequency is offset from the exact half line-frequency relationship by 17 times the picture frequency, as required for the BBC proposal when European 525/60 signals are radiated.

A comparison of results under the two conditions (c) and (d) above showed no significant difference in the acceptability of the subcarrier pattern in the compatible picture. In addition, the colour synchronisation performance of three commercially-produced domestic colour receivers used in the experiment did not appear to be affected by the offset subcarrier condition. It was therefore concluded that the compatibility of the NTSC signal and the performance of NTSC colour receivers would be unaffected by the change of subcarrier-frequency offset required by the BBC proposal.

In this report the results of subjective tests of the BBC and Netherlands' proposals using an experimental translating* equipment are described. The equipment was constructed so as to effect translation from the American 525/60 standard to the European 525/60 standard. This direction of colour translation was chosen for the experiments since it is the more difficult case to instrument. When translation is from the European to the American standard, the fact that the latter system has a lower bandwidth than the former makes the problem of suppression of the original subcarrier much simpler.

2. EXPERIMENTAL ARRANGEMENT

Fig. 1 shows a simple schematic of the translating equipment used for the tests. Preliminary experiments showed that if the 3·58 Mc/s American chrominance subcarrier was removed by a conventional notch filter, a very high attenuation was required over most of the chrominance band in order to remove the beat pattern between the old and new subcarriers. The attenuation required was found to be in the region of 40 dB for the Netherlands' proposal and 30 dB for the BBC proposal and, in both cases, a severe loss of luminance sharpness resulted.

In order to overcome the severe luminance impairment associated with a conventional notch filter, the arrangement of Fig. 1 uses a delay technique to separate the chrominance subcarrier and luminance signal of the American 525/60 signal. The composite American colour signal requiring translation is passed through a delay equal to that of a single scanning-line period. Addition of the input and output signals of the delay then results in a signal from which the chrominance subcarrier has been substantially removed, and subtraction of the output signal from the input signal results in a signal from which the luminance signal has been substantially removed. However, in order to avoid excessive loss of vertical resolution of the luminance signal, it is necessary to arrange that the filter formed by the delay and its associated circuits operates on only the higher-frequency components of the signal. This is achieved by the low-pass filter and associated subtraction circuit shown in Fig. 1 which form a complementary low-pass and high-pass filter arrangement.

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* The process of modifying the American (European) 525/60 NTSC colour signal to the European (American) 525/60 NTSC colour signal can conveniently be termed 'translation' to distinguish it from processes involving transcoding between colour systems, or standards conversion.

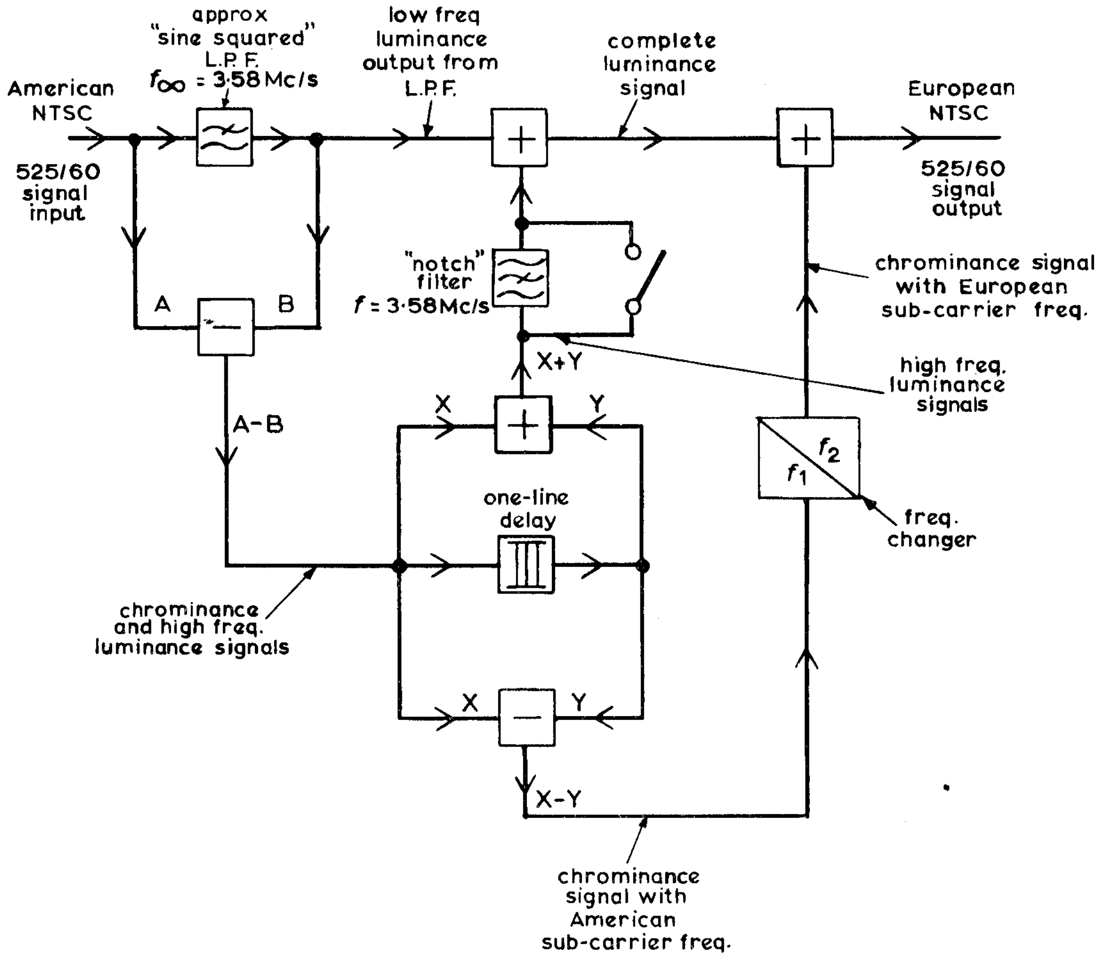
approx "sine squared" L.P.F.
f_{∞} = 3·58 Mc/s
low freq luminance output from L.P.F.
complete luminance signal
American NTSC
525/60 signal input
European NTSC
525/60 signal output
A
B
A−B
"notch" filter
f = 3·58 Mc/s
chrominance signal with European sub-carrier freq.
high freq. luminance signals
X+Y
X
Y
one-line delay
f_1
f_2
freq. changer
chrominance and high freq. luminance signals
X−Y
chrominance signal with American sub-carrier freq.

Fig. 1 - Translating equipment: simplified schematic diagram

No loss of vertical resolution, therefore, is suffered by that part of the luminance signal whose spectral components lie below the chrominance band. It is, of course, to be expected that beat patterns will occur at horizontal colour edges since the delay-type filter can reject the NTSC chrominance subcarrier only when the colour information is identical on successive lines of a field. The additional notch filter shown in Fig. 1 had high attenuation over a very narrow bandwidth and was available in order to reduce the visibility of the beat patterns occurring on horizontal colour edges whilst causing a minimum impairment of the luminance signal. The notch filter had a maximum attenuation of approximately 40 dB at 3·58 Mc/s and an attenuation of 3 dB at 3·58 Mc/s ± 30 kc/s.

Fig. 2 shows in detail the complete experimental arrangement. The 525/60 American colour signal from the coder was applied to the low-pass filter and subtractor arrangement and the high-frequency components passed to the delay-type filter. The luminance-signal output from the adder of the delay-type filter was then added to the low-frequency components of an input signal derived by the low-pass filter. The chrominance-signal output from the subtractor of the delay-type filter was fed through two mixers and their associated filters, where its frequency was changed to that of the European standard. The frequency-changing process consisted essentially of the addition, in Mixer No. 1, of the frequency of a local oscillator, f_X (approximately

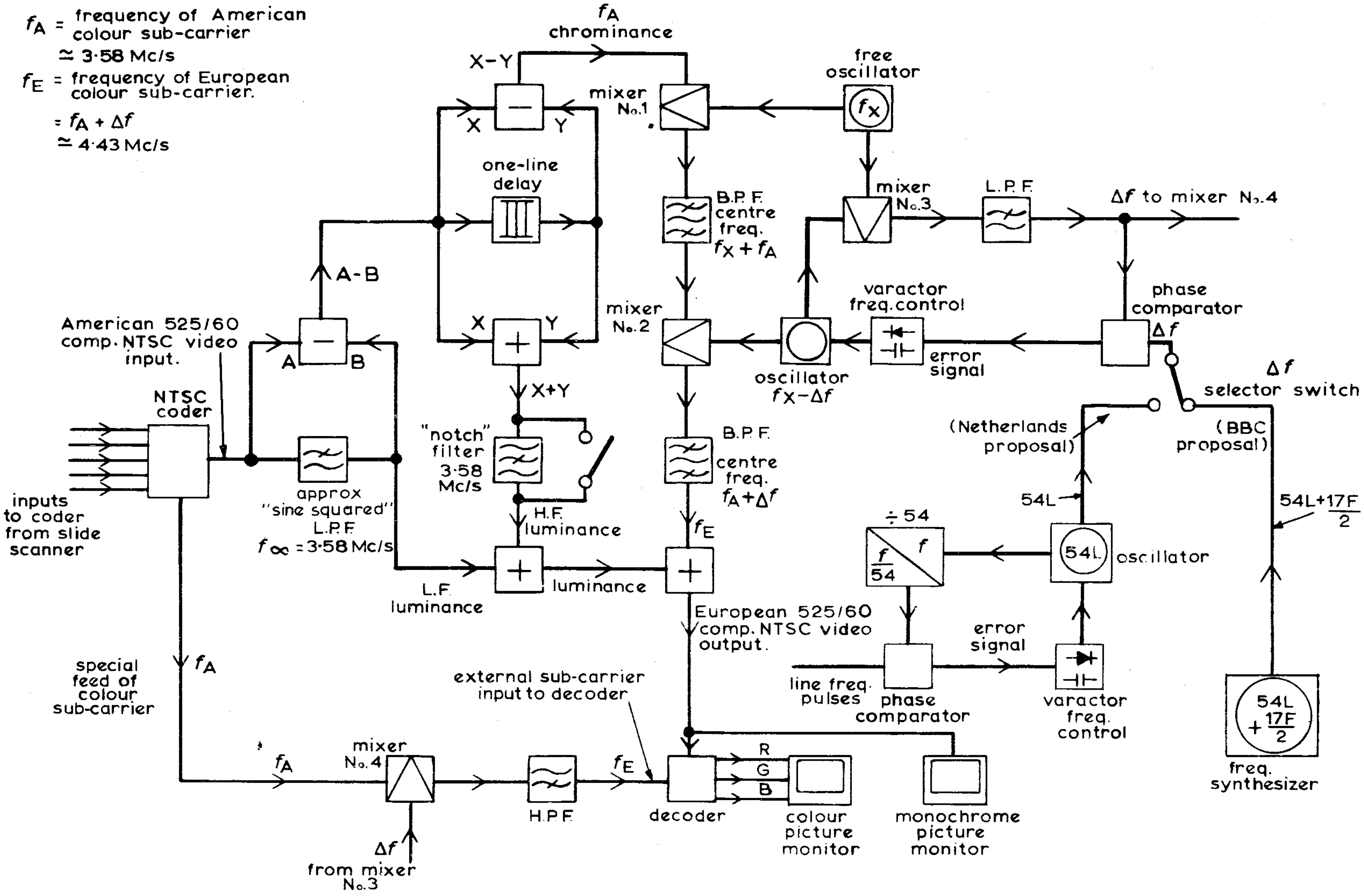

Fig. 2 - Experimental translating arrangement: schematic diagram

11 Mc/s), to the American chrominance frequency and then, in Mixer No. 2, the subtraction of the frequency of another local oscillator, $f_X - \Delta f$. The output chrominance frequency was thus Δf greater than the input chrominance frequency. The band-pass filters selected the sum or difference components of the mixer outputs as required.

The correct frequency separation of Δf between the two oscillators was achieved by beating their outputs together so that the difference frequency appeared at the output of the associated low-pass filter. This difference frequency was compared in the phase-comparator with the desired value of Δf and an error signal from the phase-comparator then controlled the frequency of the second oscillator to maintain the correct frequency difference. The values of Δf appropriate to the two proposals were obtained via the 'Δf selector switch' either from a frequency synthesiser or an oscillator, divider and automatic-phase-control loop.

The arrangement so far described led to a difficulty in the synchronisation of the demodulating oscillator in the decoder. The pull-in range of this oscillator was very much less than the 510 c/s change in subcarrier frequency which occurred when changing from the BBC to the Netherlands' proposals and direct switching between the two was not possible. Since this was purely an instrumental difficulty and not related to the practical application of either system, it was solved by obtaining a special feed of the American subcarrier signal from the coder, as illustrated in Fig. 2. This signal was changed in frequency, in Mixer No. 4, by adding a signal of frequency Δf, obtained from Mixer No. 3 and its associated low-pass filter. In this way the correct demodulating subcarrier phase and frequency were maintained at the decoder in both conditions.

3. SUBJECTIVE TESTS

When an American NTSC colour signal is translated to the European 525/60 standard, the main cause of picture impairment results from the fact that the delay-type filter removes the original subcarrier component only in those areas of the picture where the colour content is the same on adjacent lines of a field. Thus, at horizontal boundaries between coloured areas, a component of the chrominance subcarrier appears in the luminance output of the delay-type filter. This chrominance component beats with the European chrominance signal causing picture impairment in the form of spurious coarse beat patterns. These beat patterns at horizontal colour edges are found to occur in both colour and compatible monochrome pictures derived from the translated signal and are particularly objectionable when horizontal movement occurs in the scene.

Further picture impairment results from the fact that it is impossible to separate the luminance and chrominance components of the original American 525/60 signal without some impairment of the luminance signal. There is an impairment of vertical resolution in fine detail due to the addition of signals on successive scanning lines by the delay-type filter, and additional impairment occurs due to 'ringing' on vertical luminance edges when the notch filter shown in Fig. 1 is used. It must be made clear that there are two causes of the impairment of vertical resolution. The first is due solely to the action of the delay-type filter, the luminance signal output of which is formed from the luminance components of two successive scanning lines; the loss of vertical resolution due to this cause is restricted to small areas of the picture since only the higher luminance-signal frequencies pass through the delay-type filter. The second cause arises when components of the higher luminance-signal frequencies appear in the chrominance output of the delay-type filter. This occurs when adjacent lines of the television field carry dissimilar high-frequency luminance information. These luminance-signal components are changed in frequency by the colour translation process and are added back to the main signal, appearing locally on the picture as a spurious fine beat pattern. The process results in a slight loss of vertical resolution together with a simultaneous loss of horizontal resolution in regions of the picture containing, for example, sloping edges. As will be seen later, however, neither effect is very serious in practice.

The subjective tests were divided into two parts which will be referred to as Tests 1 and 2. Test 1 was an investigation of the beat pattern between the original and new subcarriers and Test 2 was an investigation of the impairment of the luminance component of the translated picture.

Test 1

Using a single colour slide (EBU 1, 'Boy with Toys') a signal on the American NTSC 525/60 standard was generated by a colour slide scanner and was then translated to the two proposed (BBC and Netherlands') European 525/60 standards by the arrangements shown in Figs. 1 and 2, the translated signal being displayed simultaneously on the colour monitor and the monochrome monitor. The observers, who were all engineers experienced in the assessment of television picture quality, were asked first to compare the Netherlands' and BBC proposals from the point of view of beat patterns using the subjective scale shown in Table 1. Although it was known that the beat patterns were more objectionable using moving pictures, only still pictures were available for the tests. Consideration was given to the simulation of movement in the scene by movement of the slide in the slide scanner but it was thought that this might lead to unreliable results. The results of a short preliminary test indicated that, although the beat patterns appeared more objectionable using moving pictures, their actual visibility was not very much affected by movement once the observers had become familiar with their appearance. The observers were therefore shown a somewhat exaggerated beat pattern before each test.

TABLE 1

Comparative Subjective Scale C

SCORE	DESCRIPTION
-3	B much worse than N
-2	B worse than N
-1	B slightly worse than N
0	B same as N
+1	B slightly better than N
+2	B better than N
+3	B much better than N

B denotes the BBC proposal.

N denotes the Netherlands' proposal.

The observers first made two comparisons:

(a) Between the BBC and Netherlands' proposals, the additional notch filter shown in Figs. 1 and 2 not being used.

(b) Between the BBC and Netherlands' proposals, using the additional notch filter shown in Figs. 1 and 2.

The observers were then asked to assess the impairment caused by the beat patterns using the subjective scale shown in Table 2.

TABLE 2

Impairment Subjective Scale A

SCORE	DESCRIPTION OF IMPAIRMENT
1	Imperceptible
2	Just perceptible
3	Definitely perceptible but not disturbing
4	Somewhat objectionable
5	Definitely objectionable
6	Unusable

The observers made four assessments:

(c) Using the Netherlands' proposal without the additional notch filter.

(d) Using the BBC proposal without the additional notch filter.

(e) Using the Netherlands' proposal with the additional notch filter.

(f) Using the BBC proposal with the additional notch filter.

Test 2

Using six monochrome slides, chosen to represent a wide range of pictures likely to occur in practice, a signal on the American 525/60 standard was generated by a monochrome slide scanner. Using a monochrome monitor, the observers were first shown pictures before translation and then were shown the same pictures when translated to the BBC and Netherlands' proposed European standards. The observers were asked to assess the impairment of the monochrome pictures using the scale in Table 2 under the following conditions:

(a) Unimpaired pictures (direct display of American 525/60 input standard).

(b) BBC proposal without the additional notch filter.

(c) Netherlands' proposal without the additional notch filter.

(d) BBC proposal with the additional notch filter.

(e) Netherlands' proposal with the additional notch filter.

4. RESULTS OF SUBJECTIVE TESTS

The results of the subjective tests are shown in Tables 3, 4 and 5. Tables 3 and 4 summarise the tests carried out to assess the visibility of beat patterns between the original and new subcarrier frequencies (Test 1). Table 5 summarises the tests carried out to determine the impairment of the luminance component of the picture resulting from the translation process (Test 2).

In the tables, each figure is the mean of the scores of the observers and the figures in brackets are the corresponding standard errors.* The results in Table 3 which use the comparative scale of Table 1 are considered significant if they are greater than twice the standard error. In Tables 4 and 5 which use the absolute subjective scale of Table 2, any two results are considered to differ significantly if the difference between them exceeds three times whichever of the standard errors is the greater.

TABLE 3

Visibility of Beat Pattern (10 Observers)

Subjective Comparisons of BBC and Netherlands' Proposals

DISPLAYED PICTURE	TEST CONDITION	SUBJECTIVE GRADE C (TABLE 1)
Colour	With notch filter	+1·4 (0·21)
Compatible monochrome	With notch filter	+1·6 (0·21)
Colour	Without notch filter	+1·8 (0·19)
Compatible monochrome	Without notch filter	+2·1 (0·22)

TABLE 4

Visibility of Beat Pattern (10 Observers)

Subjective Impairment of BBC and Netherlands' Proposals

DISPLAYED PICTURE	TEST CONDITION	SUBJECTIVE GRADES, SCALE A, TABLE 2	
		BBC PROPOSAL	NETHERLANDS' PROPOSAL
Colour	With notch	1·5 (0·21)	2·5 (0·15)
Compatible monochrome	With notch filter	1·6 (0·29)	3·2 (0·19)
Colour	Without notch filter	1·6 (0·21)	3·6 (0·19)
Compatible monochrome	Without notch filter	1·8 (0·31)	3·8 (0·18)

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* If the standard deviation of a group of N observations is σ, the standard error is defined as $\sigma/\sqrt{N}$. The standard error is a convenient means of assessing the loss of accuracy in the mean due to a finite number of observations.

TABLE 5

Impairment of Luminance Component (24 Observers)

TEST CONDITION	SUBJECTIVE GRADE SCALE A, TABLE 2
Unimpaired picture	1·44 (0·22)
BBC proposal with notch filter	3·3 (0·26)
BBC proposal without notch filter	3·3 (0·24)
Netherlands' proposal with notch filter	3·3 (0·26)
Netherlands' proposal without notch filter	2·8 (0·3)

5. DISCUSSION OF RESULTS

5.1. Visibility of Beat Pattern

Table 3 shows that the beat pattern occurring on horizontal colour edges is always more visible when translation is achieved by the Netherlands' proposal than when the BBC proposal is used and the simple statistical test described in Section 4 shows that these differences are significant. Table 3 also shows that the improvement given by the BBC proposal is similar for both the colour picture and the compatible monochrome picture.

Table 4 confirms the results of Table 3 and also shows that the additional notch filter, whilst reducing the visibility of the beat pattern in the case of the Netherlands' proposal, has little effect in the case of the BBC proposal. Even with the notch filter, however, the visibility of the beat pattern occurring with the Netherlands' proposal is greater by approximately 0·5 to 1·0 subjective grades than is the beat pattern occurring with the BBC proposal. The statistical test shows this improvement given by the BBC proposal to be significant.

5.2. Impairment of the Luminance Component of the Translated Picture

Table 5 shows that the impairment of the luminance component of the translated picture, introduced by the process of translation, is substantially the same for both the BBC and Netherlands' proposals and is relatively unaffected by the presence of the notch filter. Comparison with the unimpaired condition (the American picture before translation) shows that the impairment introduced by the translation process is between 1 and 2 subjective grades. This impairment is thought to be largely due to the loss of vertical resolution inherent in the filtration process used to separate chrominance and luminance. Table 5 shows that an appreciable impairment of the luminance component occurs with either proposal. When studying these results, however, it must be remembered that the experimental nature of the equipment may have introduced some impairment of the luminance component and also that the observers were trained engineers and were therefore more critical than the average viewer. It is thought that the impairment of the luminance component would be acceptable in service transmissions.

5.3. Total Impairment Introduced by the Translation Process

In Sections 5.1 and 5.2 tests concerning beat patterns in the translated picture and impairment of the luminance component of the translated picture were discussed separately. These tests enable the two proposals for dual-standard colour television to be compared and show that the BBC proposal will result in the smaller impairment. However, it is clearly desirable to have some knowledge of the total impairment introduced by the process of translation. Unfortunately, it was necessary to estimate this total impairment since a decoder of adequate performance was not available for the American standard; it was not possible, therefore, to compare directly the original and translated pictures. In estimating the total impairment it must not be forgotten that the presence of the NTSC subcarrier makes it impossible to obtain an unimpaired colour or compatible monochrome picture before translation. Bearing this in mind, it is thought that in practice the total impairment introduced by either translation process would be approximately one subjective grade on the absolute scale (Table 2); the impairment using the BBC proposal would, however, be less than that using the Netherlands' proposal. It is felt that an impairment of this magnitude would be acceptable when translating American programmes.

6. CONCLUSIONS

The tests described in this report show that either the Netherlands' or BBC proposals for dual-standard colour television could be instrumented so as to give acceptable translation between American and European NTSC signals on the 525/60 standard. However, the BBC proposal results in a significant reduction in the visibility of beat patterns between the original and translated colour subcarrier as compared with the Netherlands' proposal. It would probably be possible to reduce the beat patterns obtained using the Netherlands' proposal by means of more severe filtering, so as to make the two proposals equal in this respect, but the loss of sharpness of the luminance component would then be greater in the case of the Netherlands' proposal.

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